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Comfort, climatic background and adaptation time: first insights from a post-occupancy evaluation in multicultural workplaces

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Abstract:
One of the effects of globalization and work mobility is the increasing multiculturalism in the workplace. While contemporary design policies for energy efficiency and comfort regulations are moving towards the adoption of models customized for local communities, consideration on the co-existence of people with different origins is underestimated in the current comfort debate.
The aim of this study is to show whether building occupants' comfort rating can be affected by their climatic background as well as their duration of living in the current country of residence.
A post-occupancy evaluation (POE) was carried out in two office buildings located in Switzerland accounting for a high rate of international employees. Questionnaires were distributed among the building occupants with the aim to investigate, among other things, their satisfaction with temperature, air quality, lighting, noise, view to the outside and privacy.
With regard to thermal comfort and air quality, the results show that indeed people's rating varied significantly according to their climate of origin as well as with the time span spent in the country. However, no statistically significant differences were found in terms of their satisfaction level with the other above-mentioned comfort factors. Overall, the study provides new insights on the relationship between comfort perception, cultural background and people's adaptive behavior, raising questions about the appropriateness of current comfort models and design strategies to achieve adequate environmental conditions in workplaces.

Keywords: Post-occupancy evaluation, climate, thermal comfort, air quality, adaptive comfort

1. Introduction

In a world increasingly interconnected as a result of massive and fast spread of information, people and goods, our cities are becoming more and more international. In the last couple of decades, labour force mobility – both between jobs and within and between countries – has been promoted at the communitarian and international levels to contribute to «…economic and social progress, a high level of employment, and to balanced and sustainable development…» (EU Commission, 2012). This is resulting in an increasing creation of work environments characterized by a progressive integration of locals with people coming from different countries, carrying with them habits and the culture of their places of origin. This includes also their own notion of comfort, in its many aspects.

Nevertheless, as the Society for Human Resource Management stated «…even though organizations move beyond their borders and reach into other territories, not all employees are immediately "global people"…» (SHRM, 2015), underlying by this the importance for these people to incorporate and get used to new social, cultural and environmental habits in their workplace.

For many years, research on human comfort has raised awareness on the importance of extending the comfort debate from physiological to also psychological and behavioral aspects (Cole et al, 2008). An outcome of this more comprehensive approach has been, for example, the consideration of human ability to adapt to the local indoor and outdoor thermal environment, which became essential for the development of the adaptive thermal model now included in ASHRAE and European standards (de Dear and Brager, 1998; Nicol et al. 2012).

In contemporary energy and architectural design and policy, however, while an increasing awareness is raising for the adoption of climate-specific comfort models and strategies, the simultaneous presence of people with different geographic backgrounds, that occurs for example in multicultural work spaces, is almost entirely neglected.

The aim of the study presented in this paper is to broaden our understanding of the influence of people's climatic background and adaptation time to new environments to their comfort perception in workplaces. The investigation is carried out through field studies conducted in Switzerland, which is representative of international work environments. The country has indeed one of the highest proportions of foreigners among all nations (24.6% in 2015), including cities like Geneva or Lausanne that have, respectively, around 48% and 41% of the permanent population coming from abroad (Swiss Federal Statistical Office, 2017).

2. Method

Data discussed in this paper originate from an extensive post-occupancy evaluation (POE) conducted by the authors in some office buildings located in Switzerland. The POE included seasonal environmental monitoring campaigns (long term and instantaneous measurements), seasonal point-in-time comfort surveys (associated with the instantaneous measurements) and seasonal long-term comfort surveys. Only data resulting from the latter are analysed and commented in this paper.

2.1. Long term survey

Buildings' occupants who agreed to participate in the research had to fill a preliminary background questionnaire to provide some personal information such as age, gender, work type, working hours per week, country of origin and duration of their living in Switzerland.
An extensive on-line survey was sent to the buildings' occupants twice during the year 2017: the first time at the end of winter (March-April 2017) and the second time at the end of summer (September 2017). The aim of the questionnaire was to investigate, among other things, the level of satisfaction they had experienced during the two seasons with regard to comfort overall, indoor environmental quality (IEQ) factors (temperature, light, air quality and noise), view to the outside and privacy. Ratings were registered through a 7-point Likert scale, with 1 corresponding to "Very dissatisfied" and 7 to "Very satisfied". Open questions to allow participant to add their own comments were also included in the questionnaire.

2.2. Description of the case studies and of the population

For this study, data coming from two case studies were taken into account; the first (CS1) is located in Lausanne and the second (CS2) in Geneva.

They both obtained the Minergie certification, a label attesting the high-energy efficiency of new or refurbished buildings in Switzerland. This certification system relates primarily to the annual energy used by the building for heating, hot water and electrical ventilation, requiring in most cases airtight building envelopes and the use of an energy-efficient ventilation system.

The selected buildings are equipped with HVAC systems and have fixed glazing in their facades. However, every office in CS1 is provided with hopper-type opaque elements that can be manually operated to allow for natural ventilation.

The buildings were both occupied in 2015 to host prevalently research and academic personnel and are characterized by a significant foreign population. Fig. 1 describes the demographics of the two case studies: 60 answers were collected from CS1 and 130 from CS2; respondents were from 17 different nationalities in CS1 and from 23 different nationalities in CS2, entailing the 75% and 56% of answers from non-Swiss employees respectively.

In both buildings, the majority of respondents have lived in Switzerland for more than 5 years, followed by a smaller percentage of people who have lived in the country for the last 2-5 years and a further reduced amount of people who have moved to the country less than 1 or 2 years before the research took place.

Based on an updated Köppen–Geiger climate classification (Peel et al., 2007), building users were grouped in 3 categories depending on their country of origin:

- Hot-summer Mediterranean climate (M): includes those countries generally lying between the tropics and the polar regions, characterized by hot to mild temperatures all year round (average temperature above 22°C in the warmest month and between 0° and 18°C in the coldest).
- Temperate Oceanic and Continental climate (OC): includes those countries characterized by cold winters (average temperature ≤ 0°C) and mild (temperate oceanic) to hot (continental) summers.
- Tropical and Humid Subtropical climate (TS): includes those countries typically lying at tropical and subtropical latitudes (generally between latitudes 35 north and south of the Equator), characterised by warm to hot summers and mild (subtropical) to warm (tropical) winters.

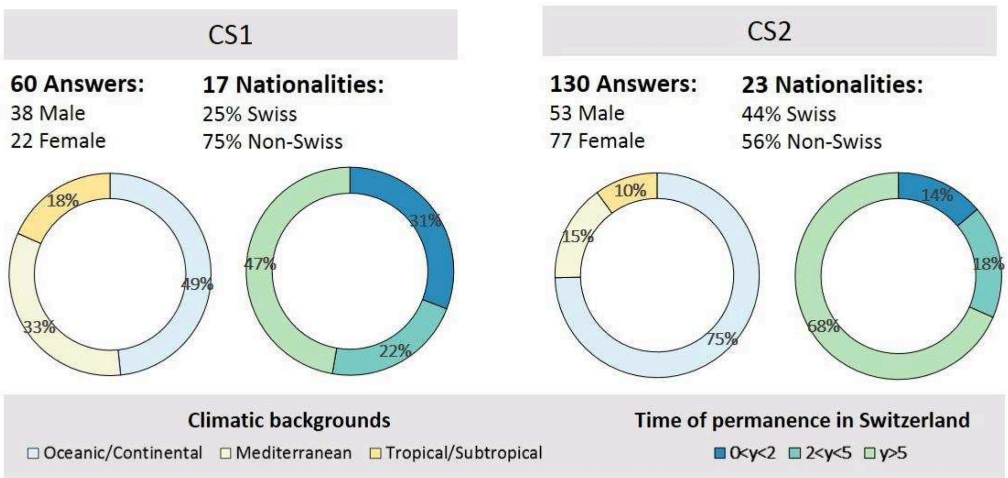

Figure 1. Demographics of the two case studies

2.3. Data analysis workflow and statistical methods

Preliminary analyses of the IEQ ratings showed great differences between the occupants' satisfaction levels in CS1 and in CS2: they revealed, on average, positive votes in CS1 – though with a considerable percentage of dissatisfied occupants in terms of temperature ratings (48%) –, while a high rate of dissatisfaction was observed in CS2, in particular with regard to temperature and air quality (always >50% of negative votes).

This initial observation raised the question whether the building design *per se* could play a main effect in the votes of the occupants and whether, as a consequence, data from each building had to be assessed individually. A multifactor analysis of variance (ANOVA) was conducted towards this end and confirmed the prevalent effect of the building on all the considered comfort factors, leading to the decision of analysing the datasets of CS1 and CS2 separately. The multifactor ANOVA also revealed a significant effect of gender and office orientation on the comfort responses. Further multifactor ANOVA tests excluded however the interaction of these two factors with the independent variables under consideration in this study, i.e. climate and time spent in the country.

Shapiro-Wilk tests and Q-Q plots revealed non-normal data distributions for both buildings, entailing the application of non-parametric testing for statistical analysis. Kruskal-Wallis test was used to assess the statistical significance (NHST, Null Hypothesis Significance Testing) of the difference in people's satisfaction votes based on their climatic background (OC, M and TS); and their duration of living in Switzerland (0-2y, 2-5y, >5y).

When a significant effect was found, a post-hoc test using Mann-Whitney test with Bonferroni correction was applied to check the statistical significance of the difference between pairs of groups. For both Kruskal-Wallis and Mann-Whitney tests, results were declared statistically significant when the probability that a difference could have arisen by chance was below 5% ($p \leq 0.05$). To infer whether the differences detected have any practical relevance, the effect size was also estimated through the formula: $r = z/\sqrt{N}$, where N is the total number of samples (Fritz et al. 2011). In interpreting the outcomes, benchmarks (in absolute values) were used to indicate small ($0.1 < r <= 0.3$), medium ($0.3 < r <= 0.5$) versus large ($r > 0.5$) effects. Statistical tests were performed with the *R software.*

3. Results

3.1. Influence of the climate of origin

Table 1 provides the descriptive statistics from the analysis of the long-term questionnaires based on the climatic backgrounds of the buildings' occupants. For each investigated comfort factor, the table presents the means and the medians of the occupants' satisfaction votes in the three climate groups and the interpretation of their statistical significance (p).

Table 1. Summary of comfort factor scores (means and medians) based on the climatic background and statistical significance of the difference between the groups

	CS1				**CS2**			
	OC **M│Mdn**	M **M│Mdn**	TS **M│Mdn**	*p*	OC **M│Mdn**	M **M│Mdn**	TS **M│Mdn**	*p*
Ov. Comfort	5.04│6.00	5.44│6.00	5.75│6.00	n.s.	3.92│4.00	3.95│4.00	3.80│4.00	n.s.
Temperature	**3.96│3.50**	4.78│5.00	**5.75│6.00**	**0.03***	3.48│3.00	3.32│3.00	3.07│3.00	n.s.
Air quality	5.18│5.50	5.67│6.00	5.75│6.00	n.s.	**3.20│3.00**	3.37│3.00	**4.27│4.00**	**0.05***
Lighting	4.93│5.00	4.61│5.00	5.25│5.50	n.s.	3.91│4.00	3.70│3.50	4.80│6.00	n.s.
Acoustics	4.86│5.00	5.11│6.00	6.00│6.00	n.s.	4.74│5.00	5.00│5.00	5.20│5.00	n.s.
View out	5.46│6.00	5.83│7.00	5.92│6.00	n.s.	4.05│4.00	4.21│5.00	4.60│5.00	n.s.
Privacy	4.57│4.00	5.33│6.00	5.50│6.00	n.s.	4.04│4.00	3.50│3.50	4.13│4.00	n.s.

***p<0.001; **p<0.01; *p<0.05; n.s. = not significant
Values in bold are those of the pairs resulting significantly different in the Mann-Whitney test

In CS1, the NHST test revealed a significant effect of the climate of origin on temperature ratings ($p = 0.02$). A post-hoc test using Mann-Whitney tests with Bonferroni correction showed, in particular, the significant differences between the groups OC and TS ($p = 0.03$), with effect size of practical relevance ($r = -0.40$).

In both seasons, scores attributed by occupants from Oceanic/Continental climate were, on average, never above the satisfaction threshold, while respondents from Mediterranean and Tropical/Subtropical climates rated the temperature more positively.

More precisely, on average the OC group found the temperature in their office “somewhat cold” (leaning towards “neutral”) in the winter and “cold” (leaning towards “very cold”) in the summer. The thermal conditions were described instead by the majority of people from M and TS groups as “neutral” for both seasons, with answers from M leaned slightly towards “somewhat cold” in winter and answers from TS lean slightly towards “somewhat hot” in summer.

No significant difference between climate groups was detected with regard to the other IEQ factors nor with view to the outside and privacy. However, a clear trend can be recognized between the groups: occupants with Tropical/Subtropical climatic background expressed on average always a higher satisfaction for all the comfort factors, followed in sequence by participants from Mediterranean and Ocenic/Continental climates (except for lighting, which is rated slightly lower by M than by OC).

These variations in ratings of CS1 are more clearly depicted by the radar chart of Fig. 2 (left), where the areas defined by each climate groups can be interpreted as their grade of tolerance toward the working environment.

A lower performance of CS2 led to generally poorer mean comfort votes for all groups in this building. No statistically significant effect of the climatic background was found on comfort ratings in this case, except for air quality in the Mann-Whitney pairwise comparisons between OC and TS ($p=0.05$, $r=-0.22$). From the comfort profile in Fig. 2 (right), however, TS showed again a higher level of satisfaction for all factors, except temperature and overall comfort whose rating was more or less equivalent to the other groups and on average always below the satisfaction threshold.

To sum up, this analysis showed that the rating of temperature in CS1 and of air quality in CS2 were significantly influenced by the climate of origin of the building occupants, and that people from the Tropics and Subtropics were generally more tolerant towards the indoor environment than people from colder countries. (Fig. 3).

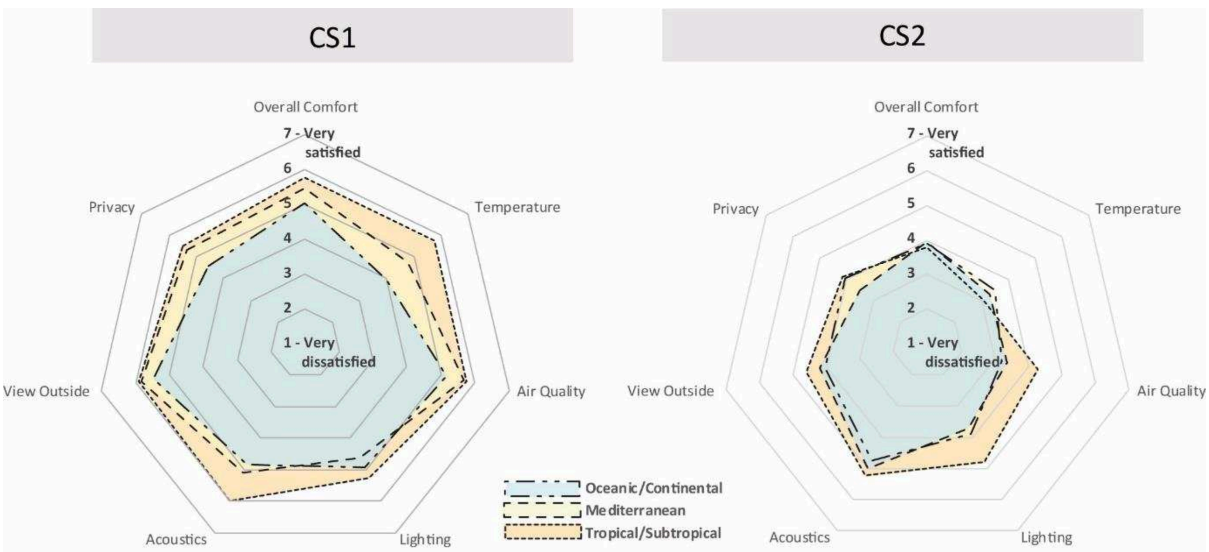

Figure 2. Comfort rating profiles based on climate of origin in CS1 (left) and in CS2 (right)

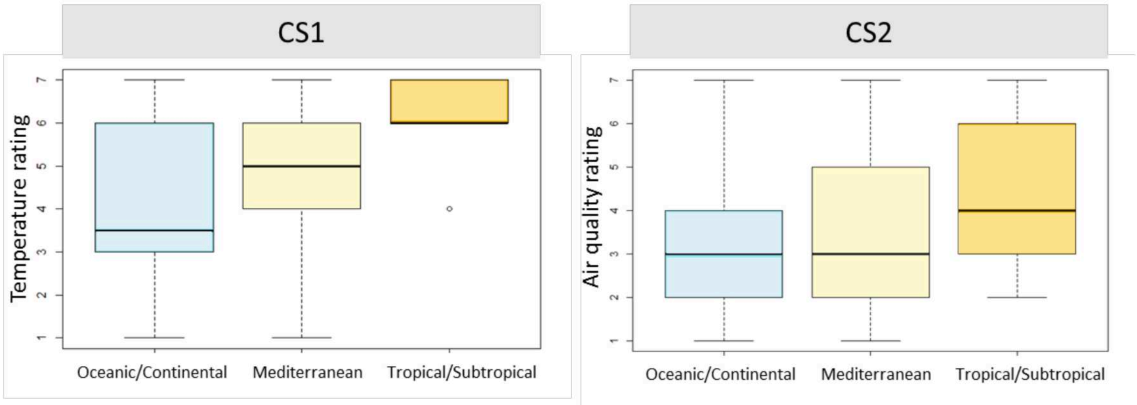

Figure 3. Rating distributions for temperature in CS1 (left) and air quality in CS2 (right) based on climate of origin (1 corresponds to "Very dissatisfied" and 7 to "Very satisfied")

3.2. Influence of the duration of residence in the country

As shown in Table 2, the score for temperature in CS1 and for air quality in CS2 were found to be affected also by how long the occupants have been living in Switzerland. More precisely, significance testing revealed differences between the groups "0-2y" and ">5y" in temperature ratings (p=0.05, r=0.35), with thermal comfort attaining very positive score in CS1 during the first two years of living in the country, while it moves towards a neutral opinion over time (Fig. 5).

In CS2, the NHST test showed a significant effect of duration of residence in the country on air quality (p = 0.02). A post-hoc test confirmed, also in this case, the significant differences between the groups "0-2y" and ">5y" (p = 0.02, r=0.26). In particular, air quality was rated positively by the majority of occupants having moved recently to Switzerland while it became more and more dissatisfying as the duration of the stay increased.

42% of dissatisfied votes recorded in the winter and 58% in the summer attributed the reason of their discomfort to "air too stuffy". Other reasons invoked were "air too smelly" (28% in the winter and 23% in the summer) and "air too dry" (28% in the winter and 19% in the summer). As the point-in-time measurements taken during the POE revealed CO_2 concentrations in the air always within acceptable limits, one may associate discomfort votes to psychological rather than physiological reasons. It could be argued, however, that the time spent in the building rather than the duration of residence in the country could also be the cause for the increasing rate of dissatisfaction in this case. Nevertheless, descriptive statistics showed that people who had started to work in the building for less than 6 months were actually the least satisfied with air quality. Significance tests confirmed in any case that there was no relationship between satisfaction with air quality and the time spent in the building.

To summarize, this analysis demonstrated that the rating of temperature in CS1 and of air quality in CS2 were significantly influenced not only by climatic background but also by the time spent in the country, and that people's opinion for these factors tended to become more negative over time (Fig. 5). With regard to the other aspects of comfort, for occupants who spent less than 2 years in Switzerland the mean votes of satisfaction were in most of the cases very close to the rest of the respondents' votes, although generally slightly more positive (Fig. 4).

Table 2. Summary of comfort factor scores (mean and standard deviation) based on duration of residence in Switzerland and statistical significance of the difference between the groups

	CS1				CS2			
	0-2y M|Mdn	2-5y M|Mdn	>5y M|Mdn	p	0-2y M|Mdn	2-5y M|Mdn	>5y M|Mdn	p
Ov. Comfort	5.56|6.00	5.42|6.00	5.04|6.00	n.s.	4.11|4.00	3.96|4.00	3.85|4.00	n.s.
Temperature	**5.38|6.00**	4.83|5.00	**3.80|4.00**	**0.05***	3.56|3.50	2.77|2.50	3.54|3.00	n.s.
Air quality	5.63|6.00	5.92|6.00	5.28|6.00	n.s.	**4.39|4.50**	3.45|3.00	**3.11|3.00**	**0.02***
Lighting	5.00|5.00	4.25|4.50	5.12|5.00	n.s.	4.06|5.00	4.13|4.00	3.92|4.00	n.s.
Acoustics	5.00|5.50	5.25|6.00	5.20|6.00	n.s.	4.72|5.00	4.96|5.00	4.82|5.00	n.s.
View out	5.44|6.00	5.83|7.00	5.60|7.00	n.s.	4.22|4.50	4.14|5.00	4.12|4.00	n.s.
Privacy	5.38|6.00	5.33|6.00	4.72|4.00	n.s.	3.94|4.00	3.30|3.00	4.15|4.00	n.s.

***p<0.001; **p<0.01; *p<0.05; n.s. = not significant
Values in bold are those of the pairs resulting significantly different in the Mann-Whitney test

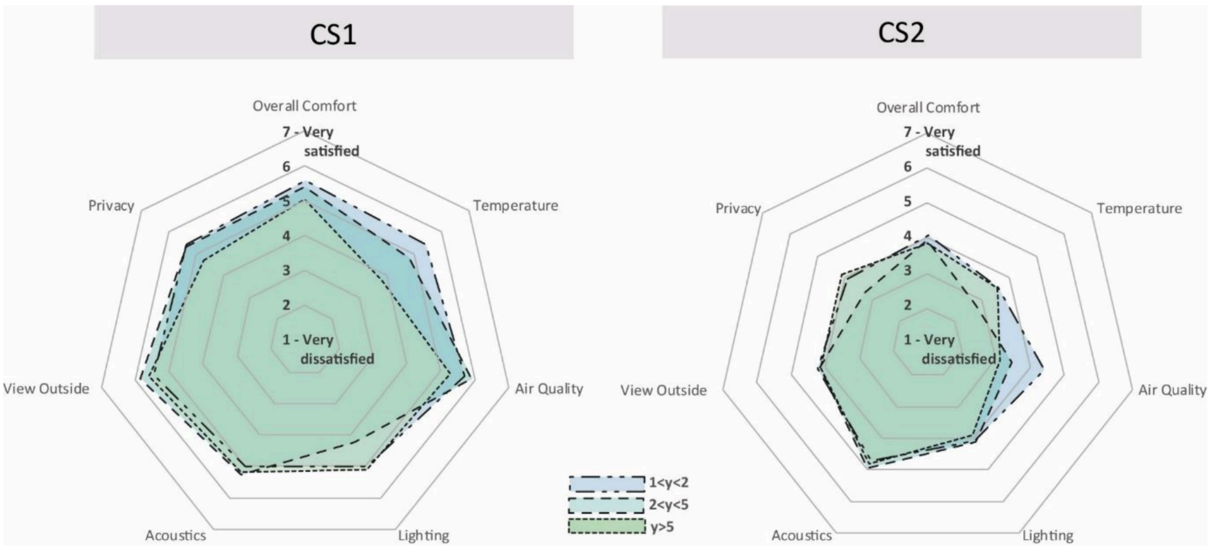

Figure 4. Comfort rating profiles based on duration of residence in Switzerland in CS1 (left) and in CS2 (right)

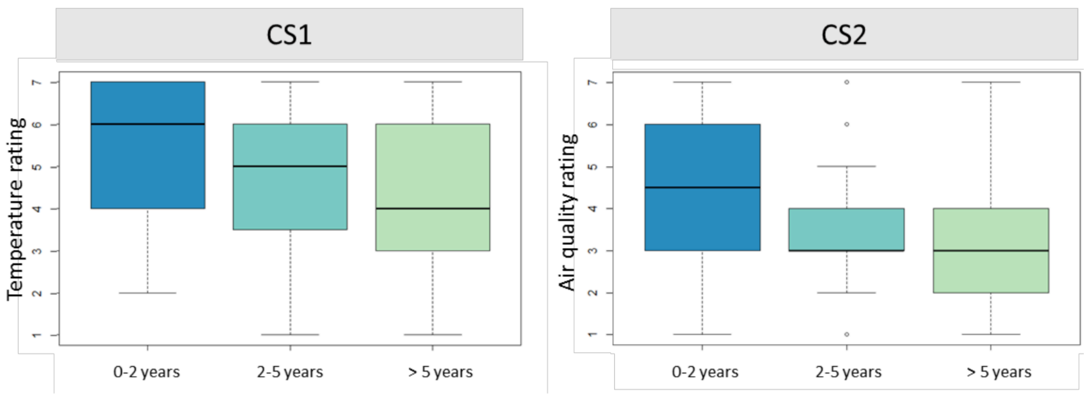

Figure 5. Rating distributions for temperature in CS1 (left) and air quality in CS2 (right) based on duration of residence in Switzerland (1 corresponds to “Very dissatisfied” and 7 to “Very satisfied”)

4. Discussion

Among all the considered comfort factors, the satisfaction with temperature and with air quality were found to be significantly influenced by the climatic background of the building users, as well as the duration of their residence in the country. The climate of origin and the time spent in Switzerland were found to be dependent variables (p-value < 0.05 in Chi-Squared test) although no interaction of the two was found in the comfort factors rating.

With regard to temperature, comparing the results between CS1 and CS2, it emerges that the influence of climatic background and of the duration of residence in the country is not substantial when the building performs very poorly (>55% of dissatisfied). On the contrary, they appear to produce an effect when the building thermal performance becomes more acceptable (67%(±5%) of satisfied and neutral opinions).

With regard to air quality, satisfaction doesn't vary significantly with the climate of origin or the duration of residence in Switzerland in CS1 where it is rated positively by over 70% of respondents, but it does in CS2 where 58%(±3%) of respondent were not satisfied.

From this particular study it emerged, therefore, that if the building performs very poorly there is no observable effect of climatic background or time of residence in Switzerland on satisfaction with temperature, but there is for air quality. On the contrary, if the building performs generally well, an influence of the climate of origin and duration of permanence in the country becomes evident on temperature ratings but not on air quality votes. To what extent the building performance plays a role in detecting a difference in comfort rating is however difficult to establish.

On the other hand, the study shows that people from Tropical/Subtropical and Mediterranean climates generally tend to be more tolerant towards indoor environmental factors than people from Oceanic/Mild summer continental climates. In particular, a significant difference between OC and TS was found for temperature ratings in CS1, showing that employees from warmer regions were comfortable in lower ranges of temperature than occupants from colder countries. This may be explained by the fact that people from the Tropics and the Subtropics are generally more accustomed to work in air-conditioned buildings with little to no mechanical heating operating in the coldest days of the year. This hypothesis would in fact be consistent with results from a test room experiment conducted by Kalmár (2016) where he observed that people with warmer thermal background preferred lower temperatures than people from a colder country. In spite of this fact, he found that after 1.5 hours exposure to a very warm environment (30°C), subjects from colder regions felt "slightly warm" or warmer while those from warmer regions tend to rate their thermal sensation as neutral, showing a generally more tolerant attitude. Reactions to very warm environments were not possible to observe in our case, because of air-conditioning use.

Moreover, these findings are actually also aligned with a study that explored outdoor thermal comfort perception in urban public places of multicultural cities showing significant differences in terms of thermal sensation votes' depending on cultural and climatic backgrounds of the interviewees (Kenawy and Elkadi, 2013).

Another aspect that is worth to mention is that, irrespective of climate groups, all median votes for temperature were more positive in the winter than in the summer. This could reveal the inappropriate design and application of air conditioning and mechanical ventilation over personal control and passive strategies for the indoor environment adjustment (i.e. thermostats, windows and shading operation), especially in a climate with generally mild summers. The absence of personal environmental control (PEC) on natural ventilation and air-change is also found in the present study as the main source of dissatisfaction with air quality in CS2.

Based on these observations, the grade of PEC and people's level of adaptation to it over time, could explain why the duration of residence in Switzerland was found to also affect temperature and air quality scores. It would be interesting to complement this result with similar studies conducted in building occupied for more than 2 years, as this would allow to draw more robust conclusions on the time spent in the buildings rather than the time spent in the country. Why satisfaction with air quality in CS2 (median values) differs between climatic groups is harder to understand but could be justified again by a more tolerant attitude towards mechanical ventilation system adopted in warm climate countries.

Considering the nature of the study, a major limitation has to be acknowledged in the relatively small size of some considered samples. It cannot be excluded that more significant effects of climatic background and adaptation time could be detected in similar studies that involve a greater population.

5. Conclusions

This paper aimed at exploring the influence of climatic background and duration of residence in a country on the level of satisfaction with comfort in one's workplace. The study was conducted through a post occupancy evaluation, during which a total of 190 on-line comfort surveys were gathered from two energy-certified office buildings.

Three main conclusions can be drawn from this study:

- Climatic background was found to have a significant influence on temperature and air quality rating. Other studies (as described in the discussion section) had demonstrated the influence of climatic and geographic background on thermal comfort in outdoor environments and in test room experiments. The study presented in this paper is the first, to our knowledge, to show how crucial the comfort issue can be in multicultural workspaces. Most importantly, findings from this study led to the paradoxical evidence that environmental conditions dictated by regulations developed for a specific country and climate are more largely accepted by people with other origins. In this sense, findings suggest reconsidering existing comfort and energy guidelines for building design and operation, confirming the necessity to move towards an architecture able to be not only sustainable but also culturally inclusive.
- It was also found that temperature and especially air quality ratings tend to decrease as the duration of residence in the country increases. This type of insight supports the adaptation theory based on which the notion of comfort can vary as time goes by depending on a series of environmental and non-environmental factors. It seems that a possible explanation for occupants' increasing dissatisfaction over time is the unresolved disappointment in the level of personal control of the environment.

Consistently with the study from Fergus (2017), which concluded that people in residential buildings accept a very wide range of satisfying indoor temperatures, these outcomes – especially if complemented with further research of this kind – may suggest the need for a revision of current protocols for energy design and certification to determine acceptable indoor temperatures and systems for personal environmental adjustment, especially in mechanically conditioned buildings. Results from the current study can, for example, further encourage studies on comfort personal control systems, and more specifically on the potential of low-power devices for the control of local thermal environment that are currently conducted to provide people with systems to remain comfortable over a wider range of ambient temperatures (Zangh et al. 2015).

- Last but not least, despite not being the focus of this paper, one important finding of this study was that buildings constructed in the same period, with equivalent programs and which obtained the same energy label, can respond to users' comfort expectations in very different ways. The influence of the building design was so significant in the comfort ratings of their occupants that the option of analyzing data as a whole had to be abandoned. Results from this paper reiterate the necessity, which already emerged in several studies on energy-efficient architecture, to consider contemporary environmental design regulations as challenges to enhance our built environment rather than barriers that prevent to meet architectural quality and, above all, users' comfort and satisfaction.

6. References

Cole, R. J., Robinson, J., Brown, Z., & O'Shea, M., 2008. Re-contextualizing the notion of comfort. *Building Research & Information*, 36(4), pp. 323–336

de Dear, R.J., Brager, G.S. 1998. *Developing an adaptive model of thermal comfort and preference*. ASHRAE Tech Data Bull, 14 (1), pp. 27-49.

EU Commission, Directorate-General for Employment and Social Affairs, 2002. *High Level Task Force on Skills and Mobility: Final Report*. Office for Official Publications of the European Communities.

Fritz, C. O., Morris, P. E., & Richler, J. J. 2011. Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General, 141*(1), pp 2-18.

Kalmár, F., 2016. Investigation of thermal perceptions of subjects with diverse thermal histories in warm indoor environment. Building and Environment, 107, pp. 254-262.

Kenawy, I., Elkadi, H., 2013. The impact of cultural and climatic background on thermal sensation votes. In: PLEA2013, *29th Conference, Sustainable Architecture for a Renewable Future*. Munich, Germany.

Nicol, F. 2017. Temperature and adaptive comfort in heated, cooled and free-running dwellings. *Building Research & Information*,45 (7), pp. 730-744

Nicol, F., Humphreys, M., Roaf, S., 2012. Adaptive Thermal Comfort: Principles and Practice. Routledge, London; New York.

Society for Human Resource Management, 2015. Understanding Workplace Cultures Globally. Available on-line: https://www.shrm.org/

Zhang, H., E. Arens, and Y. Zhai. 2015. A review of the corrective power of personal comfort systems in non-neutral ambient environments. *Building and Environment*, 91, pp.15-41.